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Safe production of microbial protein from urine

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Abstract: An electrochemical cell was used for ammonia extraction from urine. Extracted ammonia was free of trace elements and thus suitable for production of microbial protein. Protein quality was similar to that obtained using dAMS media for cultivation of methanotrophic bacteria.

Keywords: Single cell protein; methane oxidizing bacteria; nutrient recovery

An increasing global population is causing alarming depletion rates of many planetary resources: production of chemical fertilizers alone has increased by 500% over the last 50 years due to agricultural intensification to supply the animal and vegetable protein for human consumption. Current modes of agricultural protein production are inefficient, generate large amounts of waste, have a high land and water footprint, are energy intensive, and are ultimately unsustainable. Therefore, new and lower-footprint modes to produce protein-rich feed or food ingredients are needed. Single-cell protein (SCP) consisting of microbial biomass – grown on various resource streams – can generate nutritive proteins – with quality equal or exceeding those of traditional references like soy of fishmeal – at a lower cost than traditional protein production chains (Matassa et al., 2016). Large amounts of nutrients are excreted and conveyed into domestic sewage. Conventional wastewater management involves nutrient removal and is both energy and chemical resource intensive. As nutrients in sewage are diluted and contaminated with fecal pathogens, their safe recovery is not trivial. Yet, urine contributes 80% of all the nitrogen (N) and 50% of all the phosphorus (P) in domestic sewage in a small fraction of the total sewage volume and with minimal pathogen content. With urine separation gaining momentum a nutrient concentrated stream has become available which is suitable for recovery and upcycling (Maurer et al., 2003). The ambition of this work is to demonstrate the production of high-quality microbial protein using nutrients from urine for cultivation of methanotrophic bacteria.

A 2 chamber (200 cm^3 each cell) electrochemical reactor was used for ammonia extraction from male urine (anode chamber), using 50 mmol sodium bicarbonate solution as electrolyte in the cathode chamber (Fig. 1). Chambers were separated with a strong acid cation exchange membrane. The cathodes were made of titanium alloy (anode coated with IrO_2). The applied voltage was 3.5 V. Urine was spiked with different pharmaceuticals or recalcitrant chemicals, including 1-H-benzotriazole, 5-

methyl-1H-benzotriazole, carbamazepine, atrazine, ketoprofen, diclofenac, clofibric acid, bezafibrate, mecoprop and gemfibrozil. After 48 hours 42% of the ammonia could be extracted to the cathode chamber with an efficiency of 35%. Extracted resources were free of spiked pharmaceuticals or pesticides and thus could be used for feed-grade microbial protein production. Similar experiments were run using municipal household waste and digested manure as ammonia source.

Figure 1. Electrochemical cell with urine in anode chamber and bicarbonate solution as electrolyte in the cathode chamber.

250 mL serum bottles were used for cultivating an enrichment of methanotrophic bacteria. Bottles were filled with 80ml active cultures and 18.5 ml of the headspace were replaced with methane to ensure a favourable ratio of 60:40 of oxygen to methane. Three different sets of experiments were run: i) control experiments using dAMS medium; ii) extracted ammonia with pH correction using a phosphate buffer; iii) extracted ammonia supplied with trace elements and pH corrected using a phosphate buffer. Batches without trace elements did not support the growth of methanotrophic bacteria. However, both the control and the batch with extracted ammonia showed similar performance in terms of methane yields and microbial growth. Both showed similar amino acid profile (Fig. 2), but lacked some essential amino acids (e.g., methionine, valine and histidine) compared with already commercialized Uniprotein® microbial protein.

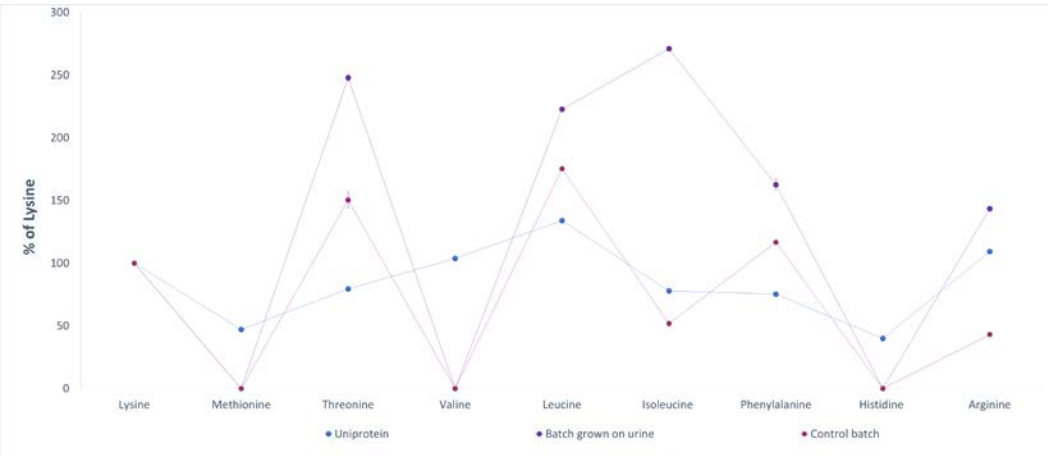

Figure 2. Amino acid distribution for the commercially available SCP Uniprotein®, from the control experiment and from the experiment where ammonia was substituted by ammonia extracted from urine.

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